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Variable Polarization States in Free-Electron Lasers

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Free-electron lasers (FELs) produce different optical polarizations including linear, elliptic and circular polarizations corresponding to the polarizations of the undulators used. X-ray FELs depend upon long undulator lines consisting of a sequence of short undulators. Linearly polarized undulators are most commonly used; hence the optical output is linearly polarized. Elliptic or circular polarizations are possible by varying the undulator orientation. Alternately, APPLE-II or Delta undulator designs produce undulating magnetic fields with arbitrary polarizations. We present a three-dimensional, time-dependent formulation that self-consistently includes two optical orientations and, therefore, treats any given sequence or combination of undulator including undulator imperfections and degradation.1 There are two principal characteristics of the formulation that underpin this capability. First, particles are tracked using the full Newton Lorentz force equations with analytic models of the undulators fields. This permits an accurate model of the interaction of the electrons with a large variety of undulator fields and orientations. Second, the electrons can couple simultaneously to two independent electromagnetic polarizations and, therefore, the optical polarization evolves self-consistently along the undulator line. We present the numerical model and give some examples using prevailing undulator configurations.

1. H.P. Freund and P.J.M. van der Slot, "Variable Polarization Control in Free-Electron Lasers,"J. Phys. Commun. 5, 085011 (2021). *This research used resources provided by the University of New Mexico Center for Advanced Research Computing, supported in part by the National Science Foundation.

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